Understanding Energy Production Mechanisms In Middle-Distance Running

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by Huang Jiamin

ABSTRACT

Research findings about energy production in the middle-distance races vary significantly. Some authors think middle-distance running is aerobic dominated and training should be focused in this direction while others have reached the opposite conclusion and that training should have an anaerobic focus. From the coaching practice perspective, a decision has to be made about what type of training is right for athletes aiming for success in these events. This article reviews recent literature on the topic and provides observations that may be valuable for coaches working with middle-distance runners. After summarising the main findings the author explains the differences between the subjects and in approaches taken by the studies in question. He concludes that 1) coaches should analyse the energy contribution balance for each individual athlete and 2) it may be more meaningful to do targeted anaerobic/aerobic training for each section of the race, rather than using one approach for the whole race.

AUTHOR

Huang Jiamin is a post-graduate student at the Shanghai University of Sports, Shanghai, China. He holds a RUN-FIT Specialist certification.

Introduction

Training strategies for middle-distance races vary significantly from coach to coach and athlete to athlete. Some focus on building an aerobic base, which involves a relatively high training volume, while others focus on high intensity training, which tends to limit the volume of training. One reason for the differences in approach that can be observed is that the contributions of aerobic produced energy and anaerobic produced energy to performance in endurance races, especially middle-distance races, is not fully understood.

From the physiological perspective, it is well known that the aerobic contribution will be more than 50% for any running event that lasts longer than one minute. If a race lasts more than three minutes it is certain that the dominant source of energy will be aerobic[1,2]. However, to be successful in high-level competitions middle-distance runners need to have good sprinting ability and speed endurance. Top 800m runners often run the last 200m of their races in 26 seconds[3] while top 1500m runners Hicham Guerrouj (MAR) and Bernard Lagat (USA) set their personal best times running their final 300m under 38.5 seconds[4].

From the coaching practice perspective, a decision has to be made about what type of training should be the focus for athletes aiming for success in these events. Coaches should be guided by science, but exactly what does the science tell us? In this article I will review recent literature on this topic and make observations that I hope will be valuable for coaches working with middle-distance runners.

Research on energy production in middle-distance running

Many researchers have concluded that the main energy production mechanism in middle-distance running is aerobic:

- NEWSHOLME, LEECH & DUESTER, MARTIN & COE and GREENE & PATE all suggest that the aerobic system provides the majority of the energy in middle-distance running (Table 1)[5, 6, 7].
- SPENCER, GASTIN & PAYNE hold that the role of aerobic system in energy production of runners is underestimated, not only in middle-distance running but even in the 400m[9].
- CHEN, quoting a previous study (Table 2), suggests that training for both middle- and long-distance events should be aerobic dominated and adds that most Chinese endurance runners have put too much emphasis on high intensity lactate endurance training, at the expense of aerobic training[10, 11].

However, there are also many studies that support the idea that middle-distance running is dominated by anaerobically produced energy or at least the percentage of aerobic-anaerobic energy is 50-50:

- XIANGZHUN finds that research on energy production has some different results for different ages, even though most studies support the idea that the aerobic-anaerobic contribution to the 1500m race to be 50-50%[4].

Table 1: Estimated contribution of the energy pathways in selected running events (from GREENE & PATE)

	percent contribution to generating ATP %	
Distance	**Aerobic**	**Anaerobic**
800m*	44-57	38-50
1500m-1mile**	75-76	22-24
3000m	86-88	12-14
5000m	87-93	7-13

*: Approximately 5-6% of the energy needs met by creatine phosphate
**: Approximately 1-2% of the energy needs met by creatine phosphate

Table 2: Energy production percentage in middle-distance running (from CHEN)

	Phosphagen %	Glycolysis %	Aerobic %
800m	10	30	60
1500m	8	20	72
3000m	5	15	80
5000m	4	10	86
10,000m	3-2	12-8	85-90

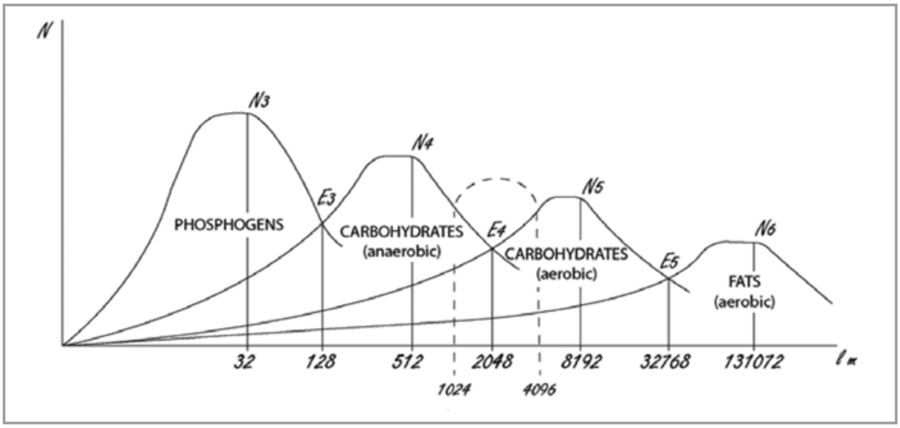

Figure 1: Metabolic sources of energy for intense running efforts (from NURMEKIVI & LEMBERG)

- NURMEKIVI & LEMBERG show their view through a bioenergetics spectrum (Figure 1)[8]. Though we can't judge the percentage accurately, we can roughly come to the conclusion that for the 800m the anaerobic system contributes more than 50%; for the 1500m the anaerobic-aerobic balance is about 50-50; and the longer events are aerobic-dominated.
- BECK[29] proposes that with increasing of age runners need more high intensity training, because high-volume aerobic training cannot compensate for the loss of strength and fast-twitch muscle fibres with aging[15]. This indicates that with the improvement of performance anaerobic ability will be more important.
- ARCELLI et al. tested 18 male 800m runners' lactate concentration during the whole race and then, using the formula developed by RITTWEGER et al.[27] and DI PRAMPERO et al.[28], calculated the contribution of the anaerobic lactic mechanism to the total energy expenditure. They conclude that for 800m runners with racing times of 1:50, 1:55 and 2:00 the contribution of lactic mechanism to the total energy expenditure is 24.9%, 24.2% and 22.2% respectively[17] (see Table 3). Considering that the contribution of the phosphagen mechanism in the 800m will be no more than 10% and that the lactic mechanism belongs to the anaerobic system, it is obvious that the authors hold the idea that the 800m is aerobic dominated.

Table 3: Energy expenditure in the 800m for performances from 105 sec to 120 sec (calculated with the RITTWEGER et al. formula), the contribution of the anaerobic lactic mechanism (calculated according to the DI RAMPERO et al. formula) and the contribution of the anaerobic lactic mechanism as a percentage of the total energy expenditure

Time over 800m (sec)	Total Energy Expenditure ml·kg^{-1}	Lactic Component ml·kg^{-1}	Lactic Component %
110	169.1	42.15	24.9%
115	167.0	40.50	24.2%
120	165.1	36.60	22.2%

When the anaerobic-aerobic percentage is analysed through the measurement of post-race lactate concentration, we find that it could be that the energy production percentage for middle-distance running is not fixed. As a part of the study mentioned above, ARCELLI et al. reviewed results of a number of studies of lactate concentration after the 800m and, as shown in Table 4, found that they vary significantly (from 12.4±1.9 to 21.9±2.1). The authors suggest that these differences could be explained by differences in study methods and subjects, inferring that post-race lactate concentration can be largely a reflection of the contribution of anaerobic lactate mechanism — the higher the lactate concentration, the more the contribution of the glycolysis mechanism to it[17].

In another study, DITROILO et al. tested 72 young regional-level athletes and found that the post-race lactate concentration after a 1500m is higher than after a 800m (15.00 vs 12.73), which seems to contradict our common sense that the shorter the race, the higher the lactate concentration[18].

Discussion

Before we draw conclusions, let's look more closely at the research itself and what might affect the results, including the difference between the subjects studied, the difference between the methods used and the assumption that energy production is the same throughout the race.

Difference between subjects

The finding of BECK[15,29] that the contribution of the anaerobic mechanism gradually increases with age in adult athletes strongly suggests that energy production in middle-distance events is age-related. For one thing, this opens the question as to whether training based on the findings of NEWSHOLME, LEECH & DUESTER, MARTIN & COE and GREENE & PATE (for adult athletes) is suitable for application to all athletes[5,6,7]. Though research based on adult athletes may tell us that middle-distance running is aerobic dominated, we can't use the research results of adult athletes to guide adolescents directly. In addition, we can see that the performance levels of the athletes selected for the studies summarised

Table 4: Mean blood lactate concentration of the scientific literature after 800m (from ARCELLI et al.)

Authors	Number of subjects	Time (s)	Blood Lactate (mmol/L)	Type of test
Lacour et al. (1990)[19]	5 (18 race)	108.4	21.9±2.1	Race
Hill (1999)[20]	5 (17 race)	120.2	18.1±2.2	Race
Duffield et al. (2005)[21]	9	126.0	12.4±1.9	Race
Thomas et al. (2005)[22]	5	120.8	17.5±1.3	Time trial on outdoor track
Bosquet et al. (2005)[23]	17	137.2	15.08±1.48	Time trial on outdoor track
Billat et al. (2009)[24]	8	129	16.9±1.9	Time trial on indoor track
Ditroilo et al. (2012)[18]	72	134.6	13.6±1.1	Indoor Athletic Race
Enrico Arcelli et al. (2012)[17]	18	118.8	14.0±1.5	Race

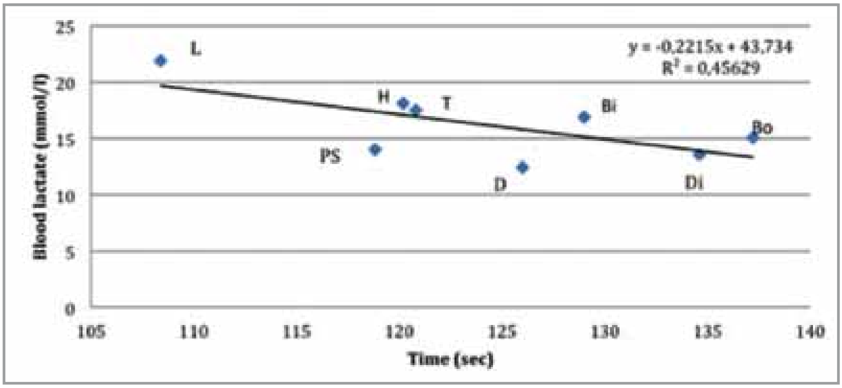

Figure 2: Trend of blood lactate concentration after an 800m as a function of the final time. Table is from ARCELLI et al. (p=0.135) (The symbols refer to the following authors: L = LACOUR et al.; PS = ARCELLI et al.; H = HILL; T = THOMAS et al.; D = DUFFIELD et al.; Bi = BILLAT et al.; Bo = BOSQUET et al.; Di = DITROILO et al.)

in Table 4 varied greatly. If we create a function based on the table we find that with the improvement of the 800m time, lactate concentration is increased so that the contribution of the anaerobic system is also increased (Figure 2). This suggests that the aerobic-anaerobic percentage in middle-distance running is related with athlete's performance level.

We should also consider whether the primary characteristic of the athlete is "speed" or "endurance", as this can also influence energy production. Compared with "endurance-type" runners, "speed-type" runners tend to depend more on the anaerobic energy system. For example, in 400m runners that had approximately the same performance level, NUMMELA & RUSKO arrived at an aerobic contribution of 37.1% in sprinter-type (average time 49.5 ± 6.0 sec) and 45.6% in endurance-type athletes (average time 49.4 ± 5.3 sec)[25]. ARCELLI et al. also suggested that "speed" type athletes have a very high lactate concentration in relation to the average values[17].

Difference between study methods

In their study of energy production in the 400m, DUFFIELD et al. found that there are some differences in the results of energy production percentage between the "accumulated oxygen deficit" method and the method that evaluates the blood lactate and estimates phosphocreatine consumption (Table 5)[21]. It seems that data for the anaerobic contribution is a little bit higher when measured with "accumulated oxygen deficit" than with "the Lactate + phosphocreatine" method.

Table 5: Contribution of the aerobic and anaerobic energetic mechanisms in 400m tests evaluated with two different methods reported by DUFFIELD et al. (from ARCELLI et al.)

Method		Aerobic Contribution(%)	Anaerobic Contribution(%)
Accumulated oxygen deficit	Men	41.9%	58.1%
Accumulated oxygen deficit	Women	44.5%	55.4%
Lactate + phosphocreatine	Men	39.2%	60.8%
Lactate + phosphocreatine	Women	37.0%	63.0%

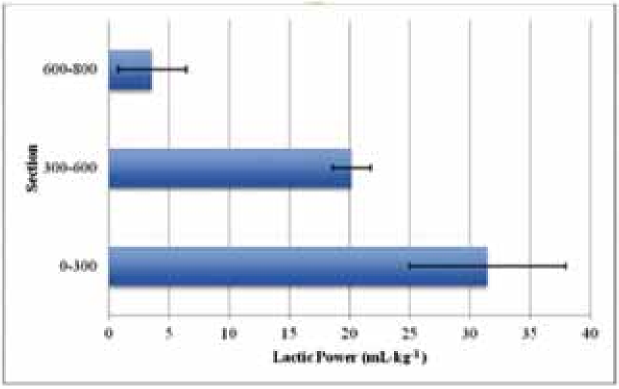

Figure 3: Contribution of the anaerobic lactic mechanism to the total energy expenditure in different sections of an 800m race (from ARCELLI et al.)

LIU found that research results on energy contribution are different at different ages, which reveals that the research results can be influenced by the development of scientific technology or performance levels in different periods.

In addition, the test conditions can also influence the result. In Table 4, the various authors chose different test environments and situations, which could easily influence the results. For example, athletes will be less motivated to push themselves fully in non-race conditions than in a race. HILL states that in laboratory experiments on the treadmill, athletes are less motivated than in races and it is quite likely that this enables them to obtain the maximum intervention of the aerobic mechanism but not of the anaerobic mechanism[20].

Energy contribution in different sections of the race

Many studies have tried to determine the energy contribution percentage over the whole course of a middle-distance race. However, it is virtually impossible for athletes to run the entire race at an even pace, so the amount of energy used and the energy contribution percentage will vary with the running velocity. ARCELLI et al. tested lactate concentration for different sections of the 800m[17]. They found that lactic power production reduces significantly from the first section (start-300m), to the second section (300m– 600m) and the last section (600m – finish) (Figure 3)[17]. With the reduction of lactic power production, the contribution of the aerobic system must increase. However, because the authors tested the athletes over 300m and 600m between two days and seven days after their 800m races the result cannot be accurate due to the lack of mental motivation as mentioned above.

Conclusion

Research findings on energy contribution in a certain event can and do influence our training theory and approach. For example, the reason why we will have marathon runners do large amounts of aerobic training compared with sprinters is because many studies have showed that marathon is aerobic dominated. However, in the case of the middle-distance races we have conflicting evidence. In addition, as ARCELLI et al. mentioned, research results can be influenced by many factors such as the subject's sex and physiological characteristics, the study methods and the performance level of subjects[26]. Thus, it's difficult to draw a simple conclusion on whether middle-distance events are aerobic or anaerobic dominated.

It may be that the best approach is to analyse the energy contribution for the athlete in question. For young middle-distance runners, because of their relatively low performance level, which makes them take more time to finish the race, it is possible that they have more of an aerobic energy contribution than adult athletes. Thus, for them or other beginners, a large amount of aerobic training is appropriate. But, with the development of performance level, the anaerobic system will become increasingly important, so it's necessary for older and more accomplished athletes to put more emphasis on anaerobic training in order to meet the demands of the race.

It may also be necessary to consider the difference of energy contribution during each section of the race. Perhaps it is more to do with targeted anaerobic/aerobic training for each section of the race, than training that is only dependent on the aerobic-anaerobic percentage of the whole distance.

Please send all correspondence to:
Huang Jiamin
932676771@qq.com

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